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Apple Thinning

With Special Reference to Grimes Golden and Jonathan

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APPLE THINNING

WITH SPECIAL REFERENCE TO GRIMES GOLDEN AND JONATHAN

C. W. ELLENWOOD AND F. S. HOWLETT

INTRODUCTION

It is relatively easy to demonstrate that thinning increases size of fruit and often improves color, but it is not so easy to establish its economic importance as compared with other cultural practices and varietal bearing habits. As more evidence accumulates on this, as well as on most other orchard practices, it becomes apparent that specific methods of procedure are restricted to relatively narrow limits. Therefore, the data and conclusions which follow are to be considered as having value as they contribute to the general knowledge of this subject and not as definite rules to be followed under all conditions.

The varieties used in the major portion of the experiments reported in this bulletin were Grimes Golden and Jonathan, both of which tend to bear heavy crops in alternate years.

The purpose of the experiment was to determine the effect of thinning the same trees, year after year, upon yield, size of fruit, color of fruit, and other tree behavior. Data from other projects at the Station having a bearing on the problem are included in the report.

METHODS OF THINNING

Apples were thinned by one of two methods: first, by simply using the thumb and fingers; second, by using a pair of light shears.

In the first method the thumb was placed against the stem with the fingers around the apple. The pressure used in removing the apple was exerted mainly by the second and third fingers. By following this plan the work was accomplished with the least wear on the hand and with the removal of a minimum of fruit spurs. If an attempt was made to remove the apples with a direct rather than a sidewise pull, one was apt to remove more apples than intended, as well as a great many clusters of fruit and the spurs themselves.

The second method of thinning consisted of using a pair of lightweight shears to cut off the apples. The best types of shears for this use have rather long, curved blades and are known commercially as "thinning", "grape", or "orange" shears. The shears shown in Figure 1 are an excellent type.

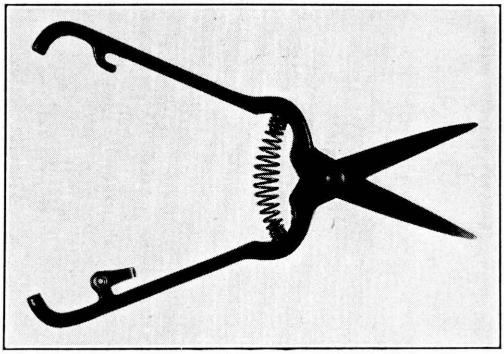

Fig. 1.—Good type of thinning shears

Each of the two methods of thinning has certain advantages, and, where much thinning is done, it is usually necessary to employ both the hand and shears methods during the course of a season.

There is an advantage in using shears in thinning short stemmed varieties and those which tend to set in clusters. Shears are also advantageous for thinning late in the season when it is difficult to separate the apples from the cluster base.

The use of shears slowed up the work considerably, as will be noted in Table 19. More bruising of the remaining apples resulted from the use of shears. Observations of the harvested apples from Yellow Transparent trees in the Station orchard thinned by the shears method showed that 14 per cent of the apples picked from the lower branches had been bruised by apples falling during the process of thinning. On the upper portion of the same tree only 4 per cent of the harvested apples showed similar bruising. From this experience it will be seen that on light-colored varieties, especially those inclined to be tender, the injury described may be quite serious. When the workman is thinning by hand he has an opportunity to drop the thinned fruit down through openings in the tree or to throw them away from the tree, with a minimum of bruising of the remaining apples.

To be economically accomplished, thinning should be done as rapidly as possible. Since the hand method is more rapid and causes less bruising, it is preferable, except under the conditions previously indicated.

Light, well proportioned, fruit ladders are essential in thinning trees more than 12 years old. For thinning younger trees and the lower portions of mature trees, a rigid step ladder is preferable. When it is necessary to climb the interior of the trees, workmen should always wear rubber soled shoes to prevent bark injury.

Thinning should be done from the top downward to permit the elimination of apples that may have been bruised by apples falling during the process of thinning the upper portions of the tree. It is important to work systematically around a tree, or many clusters will be missed.

Shaking a tree as a substitute for thinning is unsatisfactory.

PLAN OF THE GRIMES GOLDEN AND JONATHAN PLOTS

The block of trees from which the data in Tables 20, 21, 22, and 23 were taken consisted of 20 Jonathan and 16 Grimes Golden.[1] However, it was found by reference to the yield records of these trees for the preceding 19 years that three Jonathan and three Grimes trees were either considerably below or above the average. These trees which seemed to be abnormal were not included in the plots from which the data were taken. When the experiment started in 1929 the trees were 29 years old. Thinning was begun each year as soon as the "June drop" was over. In Table 1 is presented the yield record of the several plots for the 4-year period, 1925 to 1928, just preceding the beginning of this experiment.

TABLE 1.—Yield of Grimes and Jonathan
Before and after thinning experiment was started

Plot	Variety	4-year yield, 1925–1928 Average per tree	3-year yield, 1925–1927 Average per tree	3-year yield, 1929–1931 Average per tree
		Bu.	*Bu.*	*Bu.*
Not thinned	Grimes	38.8	24.9	25.4
8-inch	Grimes	63.4	47.5	47.9
10-inch	Grimes	50.4	31.7	37.0
12-inch	Grimes	55.6	38.4	37.0
14-inch	Grimes	33.0	21.6	41.8
Not thinned	Jonathan	39.3	38.8	47.2
8-inch	Jonathan	34.2	32.1	46.8
10-inch	Jonathan	40.1	35.7	40.9
12-inch	Jonathan	32.7	31.6	43.4
14-inch	Jonathan	44.1	37.9	46.6
Not pruned Thinned—8-inch	Jonathan	45.5	37.0	69.2
Not pruned Thinned—10-inch	Jonathan	34.0	31.8	59.0

[1]Hereafter in this bulletin, for the sake of brevity, Grimes Golden is referred to as Grimes.

This 4-year period included two high- and two low-crop years of each variety. In the same table is also shown the yield record for the duration of the experiment and, paired with this, another 3-year record from 1925 to 1927, inclusive. Each of these 3-year periods includes two light crops and one heavy crop of Grimes and two heavy crops and one light crop of Jonathan.

All other cultural practices have been uniform throughout the plots during the experiment. An annual application of a nitrogen-carrying fertilizer was made to all trees. A dormant spray of oil emulsion was made each year, following which the trees were dusted rather than sprayed. The trees were all growing in sod. Eight inches were taken as the minimum distance of thinning. From this distance the plots ranged by 2-inch gradations up to 14 inches. Representative trees were also left without thinning.

TABLE 2.—Relation of Thinning Distance to Mean Distance Between Adjacent Fruiting Points

Grimes and Jonathan, 1928-1931

Distance of thinning	Actual mean distance between fruiting points Inches	Deviation of mean distance from thinning distance Inches
	Grimes, 1928	
Not thinned	10.1	
6-inch	11.2	5.2
8-inch	12.4	4.4
10-inch	14.1	4.1
12-inch	13.6	1.6
Average		3.8
	Grimes, 1930	
Not thinned	9.0	
8-inch	9.7	1.7
10-inch	11.0	1.0
12-inch	13.4	1.4
14-inch	13.6	0.4
Average		1.1
	Jonathan, 1931	
Not thinned	7.4	
8-inch	12.6	4.6
10-inch	12.7	2.7
12-inch	14.3	2.3
14-inch	14.6	0.6
Average		2.6
Not pruned Thinned—8-inch	11.6	3.6
Not pruned Thinned—10-inch	11.4	1.4

The distances used refer to the minimum distance between consecutive fruiting points, measured along spur and branch. These distances are thus not equal to the mean distance between adjacent fruiting points. Several hundred measurements were taken to determine how far the minimum distance varied from the mean distance. The results of these measurements appear in Table 2. They show an average of 3.8 inches on the Grimes in 1928, 1.1 in 1930, and 2.6 inches on Jonathan in 1931 in excess of the minimum distance. These measurements also show that the 8- and 10-inch distances tend to fall in one group and the 12- and 14-inch ones in another, so far as actual mean distance between fruiting points is concerned. This similarity is also reflected to a considerable extent in the influence of thinning on size of fruit, Tables 20 and 22.

All the trees, except where noted, were pruned moderately each year. In the spring of 1927 the entire block, except the unpruned trees, was given a rather heavy pruning; so, these trees are probably somewhat less dense than is usual in commercial orchards throughout the State.

Labor for thinning these plots in 1929 and 1930 cost 35 cents per hour and in 1931, 30 cents.

From Table 3, it will be noted that, in the years 1929 and 1931, the precipitation for the 5-month period was very near the average for 41 years. In 1930, the total rainfall for the growing season was much less than the average.

TABLE 3.—Rainfall and Temperature Records at Wooster, May to September, Inclusive

For 3-year period, 1929-1931 (23)

Year	Rainfall	Mean temperature
	In.	*°F.*
1929	18.65	65.29
1930	11.33	68.25
1931	19.07	68.18
(1) Average for 41 years	18.79	66.14

The average temperature for the 5-month period during the 3 years 1929-1931 was slightly above the average temperature for the same period for 41 years. The most abnormal weather condition during the 3-year period was the drouth of 1930, which continued through much of the growing season. The influence of thinning on size is, no doubt, somewhat greater during exceptionally dry than during normal seasons.

The number of trees in each plot ranged from two to four.[2]

The values placed on both Grimes and Jonathan (Tables 21 and 23) were calculated on the following basis. Equal value was placed on size and color. In 1929 and 1930, 4 cents per pound were allowed for the fruit which graded into the first grade (both size and color considered); 3 cents for the No. 2 grade, and 1 cent for the No. 3 grade. In 1931, the three grades were valued at 1.2, 0.8, and 0.3 cents per pound, respectively. The foregoing values were approximately the selling prices for these varieties at harvest time at Wooster.

TABLE 4.—Example of Method Used for Computing Corrected Yield

Jonathan, 1929

Plot	Tree No.	Apples before thinning	Apples remaining on tree after thinning (Plot av.)	Theoretical number of apples per tree after thinning (Plot av.)	Weight per apple	Corrected weight per tree (Plot av.)
		No.	*Per cent*		*Lb.*	*Lb.*
Not thinned	407-10	4266	....	....	....	....
	408-10	4961	....	....	....	....
Av.	....	4614	....	4505	.185	833
8-inch	407- 1	4597	....	....	....	....
	408- 1	4012	....	....	....	....
Av.	....	4305	65	2928	.248	726
10-inch	407- 2	6183	....	....	....	....
	408- 2	4880	....	....	....	....
	408- 3	3886	....	....	....	....
	408- 9	3832	....	....	....	....
Av.	....	4695	58	2613	.242	632
12-inch	407- 5	3634	....	....	....	....
	408- 4	3262	....	....	....	....
	408- 5	4901	....	....	....	....
Av.	....	3832	61	2748	.266	731
14-inch	407- 6	4752	....	....	....	....
	407- 7	5646	....	....	....	....
	408- 6	5100	....	....	....	....
	408- 7	3660	....	....	....	....
Av.	....	4790	51	2298	.257	590
Av. per tree before thinning		4505	....	....	....	....

[2]It is appreciated that more trees per plot would be preferable. The labor involved in this experiment included a great many time-consuming details. Each apple removed at thinning or at harvest time was counted. The fruit from each individual tree was weighed and graded for size and color. Several hundred apples were calipered at thinning time and again when picked. Leaves on selected limbs were counted and their area calculated. The actual distance between adjacent fruits on selected limbs on the several thinned plots and other minor observations were also made. The period over which experimental thinning may be done is limited to about 4 weeks. Due to the limitation of time and the number of skilled workmen available for thinning, it was not possible to include as many trees per plot as may be more easily done with many other cultural experiments. The plan of this experiment has been to select a limited number of trees known to be relatively uniform in size and bearing habits and continue the experiment for several years.

INFLUENCE OF THINNING ON YIELD OF FRUIT

In securing the corrected weight of fruit, Tables 20 and 22, the number of fruits per tree before thinning was corrected to an average of all trees in the several plots (See example, Table 4). The theoretical number of apples per tree after thinning was obtained by using this corrected number (4505) of fruits per tree (See Table 4) as the basis and calculating each plot in accordance with the percentage of fruit which actually remained on the trees after thinning. The corrected weight per tree was then secured by multiplying the theoretical number of apples per tree by the actual weight per apple (plot average). This correction was made in an attempt to compensate for differences in the several trees, resulting in varying amounts of possible productive space. An especial effort was made to prune the trees in the plots uniformly (See Table 5), and, by making the theoretical correction, it was hoped partially to eliminate the differences in tree growth due to pruning.

This system of correction is more applicable to full-crop than to light-crop years. This fact should be kept in mind, especially in any interpretation placed on the data for light-crop years. However, the influence of thinning on yield of a tree bearing a light crop is of little consequence.

JONATHAN

Thinning Jonathan (Table 22) at any distance reduced the total weight of fruit per tree. With few exceptions the total weight of harvested fruit was reduced in proportion to the degree of thinning.

TABLE 5.—Weight of Brush Removed by Pruning Grimes and Jonathan (Spring of 1932)
Trees planted 1900

Plot	Weight of brush per tree removed by pruning (Pounds)
Grimes	
Not thinned	12.3
8-inch	22.0
10-inch	25.3
12-inch	25.3
14-inch	13.0
Jonathan	
Not thinned	31.5
8-inch	19.0
10-inch	17.4
12-inch	25.2
14-inch	19.3

These results are similar to those obtained by other workers. Rollins (24) found, after 3 years' experience in thinning Baldwin, that, for that period, the thinned trees had an average annual production of 498 pounds as compared with 682 pounds for the unthinned trees. Beach (4) also reported similar results from thinning Baldwin, Hubbardston, and Rhode Island Greening. Auchter (3), in West Virginia, found that thinning to any degree reduced total yields. Hunter (17), in British Columbia, also noted that thinning reduced total yields. On the contrary, Murneek (22), in Missouri, found that thinned Ingram and Gano slightly outyielded unthinned trees of these varieties. Thus, published results of apple thinning experiments, with few exceptions, show a net loss in weight of fruit on thinned trees. Here, as in the influence of thinning on the size of fruit, varietal differences probably account for at least part of the seeming discrepancies in results.

GRIMES

It will be noted in Table 20 that, although thinning in most instances slightly reduced the total yield of Grimes in 1930 (the heavy-crop year), the reduction was not so great as was true in the Jonathan plots. More data are needed to evaluate these differences properly.

INFLUENCE OF THINNING ON SIZE OF FRUIT

The size grades used in grading the Grimes and Jonathan plots were: (1) above $2\frac{3}{4}$ inches, (2) $2\frac{1}{4}$ to $2\frac{3}{4}$ inches, and (3) below $2\frac{1}{4}$ inches. The foregoing size grades are about the average sizes used commercially in Ohio. The machine used for sizing was one of the belt type of graders.

In 1931 the minimum sample used to determine size grades was 5 bushels per tree. Care was taken to obtain this sample from different sections of the tree to compensate for possible variation in size due to local influence. The entire crop from each tree was graded in 1929 and 1930.

JONATHAN

Thinning Jonathan at any distance materially increased the percentage of fruit in the No. 1 size (Table 22) and decreased the amount in the No. 3 size. The plots thinned to 8 and 10 inches seemed to fall in one general group, so far as size was concerned, and the 12- and 14-inch plots into another group. The difference in size of the fruit from the various thinned plots was manifested mainly in the No. 1 and No. 2 grades. The proportion of fruit in the No. 3 grade from the thinned plots, especially in the heavy-crop years, varied but little, regardless of the degree of thinning. During the two heavy-crop years, 1929 and 1931, the fruit from an unpruned tree (Table 16) thinned to 8 inches averaged smaller than that from the trees which had been moderately pruned but unthinned. The fruit from an unpruned tree (Table 16) thinned to 10 inches averaged a little smaller than that from trees pruned moderately and thinned to 8 inches. The data on the unpruned trees are not so complete as those from the pruned trees, but they indicate that moderate pruning influenced size as much as 8- to 10-inch thinning on unpruned trees.

GRIMES

The influence of thinning on size of fruit was much greater with Grimes than with Jonathan. The effect of thinning on the No. 3 grade (See Table 20) of Grimes was particularly striking. In the heavy-crop year, 1930, almost 80 per cent of the fruit from the unthinned plot graded into the No. 3 size and none into the No. 1 size. While the bulk of the fruit from all of the thinned plots graded into the No. 2 size, none of these plots had more than 11 per cent in the No. 3 size. Since the sale price differential was so much greater between Grades 2 and 3 than 1 and 2, the increased value of the fruit due to thinning (Table 21) was quite marked. As might be expected, during the light-crop years of 1929 and 1931 these differences in size grades due to thinning were not as great, but, even in those years, there was a much higher percentage of fruit from the unthinned plot in the No. 3 size than was true of Jonathan in a light-crop year.

In 1928, the same block of Grimes trees included in Tables 20 and 21 was thinned to distances ranging from 6 to 14 inches. Because the plots were changed to some extent in 1929 to provide a better arrangement, detailed data of the results of the 1928 thinning are not presented. There was, however, a striking similarity between the results of 1928 and 1930, both heavy-crop years, so far as size and yield of fruit were concerned. In 1928, the percentage of fruit below $2\frac{1}{4}$ inches on the unthinned Grimes plot was not so great as in 1930. However, it did exceed the amount of Jonathan in that size grade from unthinned trees in heavy-crop years.

The general tendency was for the percentage of the No. 1 size to increase with the severity of thinning. However, at the prices used as a basis for calculating values in 1930, the differences between the average value per pound of fruit from the 8-inch and the 14-inch Grimes plot were not very great, ranging from $.029 to $.030 per pound. The main difference in total value was between unthinned and thinned trees regardless of the degree of thinning, the value of the unthinned plot being an average of $.0140 per pound.

From the data reported in Tables 20 and 22 it will be seen that thinning to any degree consistently increased the average size of the fruit of both Jonathan and Grimes. Hunter (17), in British Columbia, found that, although thinning reduced total yield, it increased size. Auchter (3) reported from West Virginia that apples thinned to 9 to 10 inches produced a higher percentage of large fruit than at shorter thinning distances. Rollins (24) found that thinning Baldwin 4 to 6 inches increased the percentage of fruit in the larger sizes.

Gaston (10), in making an analysis of cull apples of 10 standard varieties, found that lack of size accounted for 26 per cent of the total amount of culls and for 40 per cent of the B grade. It was the most important single factor in placing fruit in the B grade and ranked second in importance in placing fruit in the cull grade.

The chief advantage in thinning is the increased average size of the fruit; but, as shown elsewhere in this bulletin, increased size, if attained at too great a sacrifice in total yield, may not increase the total value of the fruit per tree.

Varietal difference in the response to thinning is probably more manifest in the influence on size than in any other way.

INFLUENCE OF THINNING ON COLOR OF FRUIT

The Jonathan apples from the experimental plots were graded for color each of the 3 years, as shown in Table 6. U. S. color specifications (5) were followed. To qualify for U. S. Fancy it was necessary that an apple have 50 per cent over color and for U. S. No. 1, 25 per cent.

In 1929, a heavy-crop year, the fruit from all the thinned Jonathan plots was appreciably better colored than that from the unthinned plot. In that year, the gain in color due to thinning was almost enough to pay for the cost of the labor used in thinning. In 1930, a light-crop year, thinning had no significant influence on color, the fruit from the unthinned plot having slightly better color than that from all but one of the thinned plots. In 1931, with another heavy crop, the color difference between thinned and unthinned Jonathan was not significant.

Comparing the color of the fruit from the unpruned trees in 1929 and 1931 (Table 16) with that of the pruned trees, it will be seen that pruning exerted much more influence on color than did thinning. Although the data presented here are not conclusive, it is apparent that thinning will slightly improve the color of Jonathan in full-crop years but that the influence of thinning is much less on color than on size of fruit.

Experiments by workers in other states have shown a greater influence on color from thinning than was true in the work reported in Table 16. Beach (4) reported that the color of Baldwin and Hubbardston was superior on thinned trees. Rollins (24) showed a gain of 5.73 per cent in color on Baldwin over a 3-year period.

TABLE 6.—Influence of Thinning on Color
Jonathan 1929-1930-1931

Plot	U. S. Fancy Per cent	U. S. No. 1 Per cent	Under U. S. No. 1 Per cent
1929			
Not thinned	72.3	20.8	6.9
8-inch	78.1	20.8	1.1
10-inch	78.6	19.9	1.5
12-inch	83.1	15.6	1.3
14-inch	85.4	13.3	1.3
1930			
Not thinned	96.2	3.8	....
8-inch	92.2	7.8	....
10-inch	95.2	4.7	0.1
12-inch	96.4	3.5	0.1
14-inch	94.3	5.4	0.3
1931			
Not thinned	84.5	10.3	5.2
8-inch	85.2	9.8	5.0
10-inch	87.9	9.1	3.0
12-inch	84.6	11.5	3.9
14-inch	82.5	13.3	4.2
3-year average			
Not thinned	84.3	11.6	4.1
8-inch	85.2	12.8	2.0
10-inch	87.2	11.2	1.6
12-inch	88.0	10.2	1.8
14-inch	87.4	10.7	1.9

No record was made on color of the Grimes in this particular experiment; however, no special color differences were observed in grading the fruit. Gourley (12) found that Grimes from thinned trees were yellower and more highly blushed than from unthinned trees.

EFFECT OF THINNING UPON NUMBER OF LEAVES AND LEAF AREA PER FRUIT

Taking representative branches of the trees used in these experiments, the number of leaves and the leaf area per fruit were determined. Occasionally, the measurements were made on several branches of a tree. The number of fruits on the branch were counted both at thinning time and at harvest when they were also weighed. At harvest all leaves were removed, counted, and an aliquot taken for the leaf area measurements. The branches chosen in 1928 bore 500 to 2000 leaves. From 1929 to 1931 the branches were larger and bore from 2000 to 5000 leaves. The area of 25 per cent of the leaves from each limb was measured by means of the Selenium photoelectric cell apparatus designed and described by Gerdel and Salter (11). By measuring the area of 100 leaves at a time, that of 1000 leaves could be easily measured in an hour.

The selected branches were not ringed since the writers intended to obtain data on the effect of leaf area on the size of fruit under the nutritional conditions existing in the tree as a whole. The branches selected had a uniform distribution of leaves and fruits throughout and were usually so located as to be a fairly independent unit of the tree.

Grimes, 1928.—In 1928, the leaf area was measured on representative branches of nine Grimes Golden trees in their heavy-bearing year. In Table 7, in addition to the leaf area data, the average weight of a single fruit on the selected branches and the average weight of fruit on the entire trees are given.

The number of leaves per fruit increased from 15 on the unthinned tree to 56 on the tree thinned to 14 inches (Table 7). Coincident with this increase in number of leaves and a corresponding increase in leaf area, there occurred an increase in the average weight of each fruit.

TABLE 7.—Effect of Thinning Upon the Number of Leaves per Fruit, Total Leaf Area per Fruit, and Size of Fruit, in Relation to Thinning Distance

Grimes, heavy crop, 1928

Thinning distance	Leaves per fruit	Leaf area per fruit	Average area of 1 leaf	Average weight per fruit at harvest	
				Marked branches	Entire tree
	No.	*Sq. in.*	*Sq. in.*	*Oz.*	*Oz.*
Unthinned—1*	15.5	37.6	2.43	2.95	2.81
6-inch—2	30.4	56.1	1.85	3.65	3.14
8-inch—2	31.7	62.9	1.98	3.56	3.34
10-inch—1	47.1	78.4	1.66	4.23	3.51
12-inch—2	34.3	100.9	2.94	4.22	3.67
14-inch—1	56.0	127.8	2.28	4.88	4.73

*Number of trees from which leaves were removed.

Grimes, 1929.—In 1929, the light-bearing year, branches were chosen on four trees of Grimes bearing full crops. Twenty-five fruits were selected at random on each branch and their circumference measured both at thinning time and at harvest.[3] All fruits on the branches were also counted and weighed at harvest.

The number of leaves and the leaf area per fruit of the tree thinned to 8 inches were approximately double those of the unthinned tree (Table 8). The volume and weight of the fruits were doubled correspondingly. From Table 8 it is also noted that the fruits increased in size up to the 12-inch thinning distance.

Grimes, 1930.—In 1930, the heavy-bearing year, branches were selected in accordance with the spacing distances given in Table 8. No circumference measurements were made of the fruits on the selected branches, but the average weight at thinning time was determined by weighing aliquots of fruits removed from each tree. At harvest the weight of all fruits on the selected branches was taken.

The leaf area per fruit on the tree thinned to 8 inches was slightly more than double that on the unthinned tree (Table 8). The increase in weight of the fruits associated with this increase in leaf area was approximately 86 per cent. Above the 8-inch thinning there was, however, no significant increase in size of fruit. The average area per leaf on the thinned trees was larger than that on the unthinned trees.

Jonathan, 1929 and 1931.—With Jonathan in 1929 and 1931, leaves were taken from branches on two to five trees at each of the given thinning distances. In addition, the circumference of the fruits selected at random on the branches of the various trees was measured at thinning time and at harvest.

There were 25 leaves per fruit on the unthinned trees in 1929 and only 16 in 1931, with a corresponding leaf area (Table 8). In 1929 on the trees thinned to 8 inches, there was approximately a 60 per cent greater leaf area per fruit than on the unthinned trees. There was also an increase in circumference equivalent to an increase in volume of 70 per cent. The fruits increased in size up to the 12-inch thinning but by rather small increments.

In 1931, the leaf area per fruit was greater by 86 per cent on the trees thinned to 8 inches than on those unthinned, but the increase in circumference was equivalent to only a 30 per cent increase in volume. The fruits, as in 1929, increased in size by small increments up to a 12-inch thinning.

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[3]The volume was calculated from the circumference by using the formula $.5236D^3$ for a perfect sphere. Although the apple is not so shaped, the values so obtained should be relative.

TABLE 8.—Effect of Thinning Upon Number of Leaves, Leaf Area, and Size of Fruit, 1929-1931

Thinning distance	Number of leaves per fruit	Leaf area per fruit	Average area of 1 leaf	Circumference of selected fruits			Average weight of selected fruits			Average weight of all fruits at harvest
				At thinning	At harvest	Gain	At thinning	At harvest	Gain	
		Sq. in.	Sq. in.	Cm.	Cm.	Cm.	Oz.	Oz.	Oz.	Oz.
Grimes—1929 (Light crop)										
Unthinned—1*	13.3	25.4	1.91	10.6	15.6	5.0	.....	1.94	.....	.....
8-inch—1	31.1	50.0	1.61	11.6	20.0	8.4	.....	3.94	.....	.....
12-inch—1	27.6	52.5	1.80	11.5	20.4	8.9	.....	4.16	.....	.....
14-inch—1	48.0	94.6	1.83	11.4	20.5	9.1	.....	4.25	.....	.....
Grimes—1930 (Heavy crop)										
Unthinned—1	15.8	23.2	1.47	.....	.....	.....	.24	1.77	1.53	1.86
8-inch—1	31.9	48.1	1.51	.....	.....	.....	.20	3.05	2.85	3.34
10-inch—3	30.8	51.9	1.69	.....	.....	.....	.25	3.27	3.02	3.35
1 to a cluster—1	33.1	61.9	1.87	.....	.....	.....	.26	2.66	2.40	3.02
12-inch—3	40.4	65.2	1.61	.....	.....	.....	.26	2.98	2.72	3.32
14-inch—1	41.0	74.3	1.81	.....	.....	.....	.23	2.96	2.73	3.32
Jonathan—1929 (Heavy crop)										
Unthinned—2	25.1	44.7	1.78	10.6	17.7	7.1	.....	2.70	.....	2.96
8-inch—2	40.9	71.0	1.73	11.9	20.9	9.0	.....	4.02	.....	3.97
10-inch—3	49.7	87.9	1.77	11.7	20.7	9.0	.....	4.02	.....	3.85
12-inch—3	91.6	179.1	1.95	11.9	21.5	9.6	.....	4.57	.....	4.25
14-inch—4	57.0	114.4	2.00	11.2	20.6	9.4	.....	3.95	.....	4.11
Jonathan—1931 (Heavy crop)										
Unthinned—2	16.4	29.0	1.77	8.7	17.2	8.5	.25	2.40	2.15	2.72
8-inch—2	30.4	54.1	1.78	8.7	18.5	9.8	.27	3.01	2.74	3.44
10-inch—5	22.8	40.4	1.77	9.1	19.4	10.3	.28	3.22	2.94	3.36
12-inch—4	36.1	65.6	1.81	8.7	19.3	10.6	.25	3.34	3.08	3.42
14-inch—4	36.6	68.6	1.88	8.8	19.5	10.7	.29	3.26	2.97	3.54

*Number of trees from which leaves were removed.

On the basis of leaf area and increase in size per fruit, as indicated in Tables 8 and 22, the thinning fell into two groups; namely, 8 and 10, and 12 and 14 inch. Furthermore, the average area per leaf was larger at the greater thinning distances.

SIZE AND FORM OF FRUITS AT THINNING

In connection with the thinning experiments it seemed desirable to obtain information on the relation of form and size of fruits to their position in the cluster.

Statements in the literature indicate that such differences exist. Whitehouse (26) presented data showing that the relative size of a fruit at the time of thinning was a fairly accurate index of its relative size at harvest. Hinton and Swarbrick (15) and Cummings, Jenkins, and Dunning (8) agreed with this conclusion. Cummings, Jenkins, and Dunning recommended the removal of lateral fruits at thinning. Hinton and Swarbrick claimed to have data indicating that there was greater uniformity among lateral fruits and that they also have better dessert quality. In consequence, they recommend the removal of terminal fruits at thinning.

The writers examined 131 fruit-bearing clusters of Baldwin at thinning time in order to obtain definite information on the relation of the size of the fruit to position in the cluster. The clusters examined were those bearing the terminal and at least two lateral fruits. No attempt was made to distinguish between laterals. The results given in Table 9 show that 85 to 93 per cent of the terminal fruits of Baldwin was larger than the lateral fruits at thinning time. If we accept the conclusions of Whitehouse (26), Hinton and Swarbrick (15), and of Cummings, Jenkins, and Dunning (8), a terminal fruit of Baldwin would be larger than the lateral fruit at harvest.

TABLE 9.—Relation Between Number of Fruits per Cluster and Position of Largest Fruit
Baldwin, 1931

Fruits per cluster	Number of clusters	Percentage of clusters with largest fruit		
		Terminal	Lateral	No difference
3	42	85.7	2.4	11.9
4	61	86.9	11.6	1.5
5	28	92.8	7.2	0.0

TABLE 10.—Relation Between Number of Fruits per Cluster and Their Position and Form

Baldwin, 1931

Fruits per cluster	Number of clusters	Percentage of clusters of perfectly formed fruits	Percentage of fruits imperfectly formed	
			Terminal	Lateral
3	65	78.4	7.7	7.0
4	47	55.3	8.5	18.4
5	19	52.6	15.8	13.1

The fruit-bearing clusters were also examined to determine whether the terminal or lateral fruits on the cluster were of the most typical Baldwin form. The data given in Table 10 show no difference in the proportion of imperfectly formed fruits at either the terminal or lateral position. It is interesting to note that the percentage of clusters with perfectly formed fruits decreased as the number of fruits per cluster increased.

Fruit growers and horticulturists have observed that the lateral fruits usually have longer stems. Despite this fact, the writers feel that there is little evidence as yet which would justify the selection of fruits to be left on the tree at thinning time other than on the basis of size and freedom from blemishes.

EXPERIMENTS ON THE TIME OF THINNING EARLY RIPENING VARIETIES

The writers attempted to determine the effect on early ripening varieties of thinning before the June drop rather than after, as is customary. Furthermore, it seemed desirable to determine whether this earlier thinning would be unsatisfactory because of too great abscission in the June drop.

Some experiments on early thinning have already been reported in the literature. Ellenwood and Thayer (9) thinned Oldenburg on June 7 just as the June-drop fruits could be distinguished and obtained an increase in the percentage of the fruits above 3 inches over those thinned on July 4. Hunter (17) thinned Yellow Transparent, Oldenburg, Wealthy, and several other varieties at 2-week intervals from April 26 to July 19. The thinning on April 26 was at the "blossom" stage and on May 10 at the "calyx" stage. The data show that the largest sized fruits in Yellow Transparent were obtained when they were thinned at the calyx stage; whereas, in Oldenburg and Wealthy, thinning as late as June 7 (about 4 weeks after petal fall) produced larger fruits than any later thinning. Hunter concluded that fruits of these early ripening varieties may well be thinned when an inch in diameter. Auchter (3) presented data indicating that thinning York before the June drop did not prevent the abscission of fruits during the drop. Approximately 75 per cent more fruits fell from the unthinned trees than from those thinned before the June drop. Auchter reported that a considerable number fell from the thinned trees during the drop, but the percentage abscising was not given.

EXPERIMENT WITH YELLOW TRANSPARENT

An experiment was begun in 1930 to determine the effect of thinning before the June drop upon the subsequent abscission of the fruits. A vigorous 37-year-old tree in the Station orchards was selected. About 9 days after petal fall, when the fruits were about one-half inch in diameter, clusters selected at random throughout the tree were thinned to one, two, three, and four fruits. The terminal or central fruit of these clusters was always removed. The clusters were examined after the June drop when the remainder of the tree was thinned. The data are given in Table 11. They show that 93.6 per cent of the single fruits remained on the tree after the June drop. As the number of fruits left to a cluster increased, the percentage of the fruits remaining decreased proportionately.

EXPERIMENT WITH OLDENBURG, WEALTHY, AND RED JUNE

In 1931, thinning before and after the June drop was compared on whole trees of the varieties Oldenburg, Wealthy, and Red June. The trees were from 31 to 38 years old and were growing in grass mulch, with annual applications of a nitrogen-carrying fertilizer.

Oldenburg Trees 133 and 132 and Red June Trees 499 and 500 were used in pairs, both trees of each pair being adjacent and of the same age, size, and cultural treatment. One tree of the Oldenburg and Red June pairs was thinned (with the exception of two branches) before the June drop and the other tree immediately after (June 24). The two branches were thinned at the time of thinning of the adjacent paired tree.

All but two branches on two other trees of Oldenburg (Trees 400 and 228) and one of Wealthy (Tree 290) were also thinned before the June drop. After the June drop these branches were also thinned.

TABLE 11.—Relation of Number of Fruits in a Cluster to the Percentage Abscising During the June Drop
Yellow Transparent, 1930

At thinning		After June drop (June 18)						
				Percentage of clusters bearing:				
Fruits left per cluster	Clusters	Clusters with fruits	Fruits remaining	No fruit	1 fruit	2 fruits	3 fruits	4 fruits
Number	*Number*	*Per cent*	*Per cent*					
1 lateral	312	93.6	93.6	6.4	93.6	....	....	....
2 laterals	339	96.8	84.8	3.2	24.2	72.6	....	....
3 laterals	367	94.8	70.0	5.2	18.2	40.6	36.0	....
4 laterals	163	93.3	54.6	6.7	17.2	32.5	38.0	5.6

TABLE 12.—Effect of Thinning Before the June Drop Upon Subsequent Abscission
Oldenburg, Red June, Wealthy, 1931

	Percentage of fruits remaining after June drop						
	Oldenburg				Red June		Wealthy
	Tree 133 thinned before	Tree 132 un-thinned	Tree 400 thinned before	Tree 228 thinned before	Tree 499 thinned before	Tree 500 un-thinned	Tree 290 thinned before
Thinned portion:							
Fruits at random on tree	99.2	....	92.9	97.0	98.6	....	98.6
All fruits—Branch 1	99.2	....	87.6	88.3	....	....	92.5
All fruits—Branch 2	96.0	....	86.6	....	....	....	95.1
Unthinned portion:							
Fruits at random—Branch 1	34.0	51.8*	48.3	42.0	62.9	72.9*	33.8
All fruits—Branch 1	47.9	42.6	21.5	16.1	29.1	34.9	14.7
All fruits—Branch 2	25.1	22.6	....	....	32.4	38.5	....

*Fruits selected at random throughout tree.

On the thinned and unthinned portions of all trees, fruits were selected at random before the June drop and their circumference measured. After the June drop and at harvest, these fruits were again measured. Counts were also made to determine the percentage of the fruits falling during the June drop from the thinned and unthinned branches and trees.

The thinning before the June drop, as in 1930, was done when the fruits had enlarged but were still similar in size. This was about 8 to 10 days after petal fall.

The data given in Table 12 show that, on the portions of the Oldenburg trees (133, 228, and 400) thinned before the June drop, 86.6 to 99.2 per cent of the fruits survived abscission (Columns 2, 4, and 5). On the corresponding unthinned portions, only 16.1 to 51.8 per cent of the fruits remained. This range of 35 per cent was due to the fact that the measured fruits selected at random on the unthinned branches set better than all the fruits on the same branches. On the Wealthy tree, 92.5 to 98.6 per cent of the fruits left survived the June drop; whereas only 14.7 to 33.8 were present on the unthinned portions. On Red June, 98.6 survived the June drop on the early thinned tree, while, on the portion of this tree left unthinned, only 29 to 62.9 per cent remained.

In Table 13 are presented the data for the increases in circumference of the fruits during the period of the June drop and until harvest. In Table 14 the circumference data have been changed to volume, using the formula for a perfect sphere ($.5236\ D^3$).

The data show that on the portions of the trees thinned before the June drop there was a significantly greater increase in size up until June 24, as compared with the unthinned portions. It is to be noted that on Oldenburg Trees 133 and 228, as well as on the Wealthy Tree 290, the fruits on the branches thinned after the June drop caught up by harvest with the fruits on the part of the trees thinned before the June drop. Consequently, the fruits on the various portions of these trees at maturity were not significantly different in size. This may be due, in part, to the possibility that the better food and moisture supply of the tree in general had a decidedly favorable effect upon size of the fruits on the two late thinned branches. However, on Oldenburg Tree 400 and on Red June 499, the fruits thinned early were, at maturity, still significantly greater in size than the fruits on the branches thinned after the June drop.

The fruits from the paired trees of Oldenburg and Red June were harvested several times and the fruit graded at each picking (Table 15). On the Red June tree thinned before the June drop, 11.5 per cent of the total crop of fruit was above 2¾ inches; whereas only 0.4 per cent was above on the tree thinned after the June drop. Furthermore, 54.5 per cent of the fruit on the late thinned tree was below 2¼ inches, and 30.1 per cent on the early thinned tree was below that size. On the Oldenburg tree thinned before the June drop, 76.5 per cent was of the largest size compared with 57.8 per cent on the tree thinned after the June drop. The early thinning decidedly increased size of fruit. This was particularly true with the small-fruited variety Red June, which usually produces a high percentage of unmarketable fruit.

TABLE 13.—Relative Increase in Circumference of Fruits Thinned Before and After the June Drop, 1931

Variety and treatment	Circumference of fruit			Gain in circumference		
	May 26	June 24	Sept. 3	May 26 to June 24	June 24 to Sept. 3	May 26 to harvest
	Cm.	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*
Oldenburg No. 133*						
Thinned portion	2.8 ± .022	14.2 ± .072	21.0 ± .138	11.4 ± .075	6.8 ± .156	18.2 ± .140
Unthinned portion	2.7 ± .023	12.4 ± .083	20.9 ± .119	9.7 ± .086	8.5 ± .145	18.2 ± .121
Difference	....	....	....	1.7 ± .114	1.7 ± .213	0.0
Oldenburg No. 132*						
Unthinned	3.0 ± .018	11.8 ± .055	19.7 ± .267	8.8 ± .058	7.9 ± .272	16.7 ± .267
Oldenburg No. 400*						
Thinned portion	3.6 ± .036	13.2 ± .074	20.0 ± .109	9.6 ± .082	6.8 ± .132	16.4 ± .115
Unthinned portion	3.3 ± .054	11.8 ± .086	18.5 ± .151	8.5 ± .101	6.7 ± .174	15.2 ± .160
Difference	....	....	....	1.1 ± .130	0.1 ± .216	1.2 ± .197
Oldenburg No. 228*						
Thinned portion	2.5 ± .028	13.9 ± .077	20.3 ± .132	11.4 ± .082	6.4 ± .153	17.8 ± .135
Unthinned portion	2.5 ± .031	12.5 ± .081	19.7 ± .150	10.0 ± .087	7.2 ± .170	17.2 ± .153
Difference	....	....	....	1.4 ± .119	0.8 ± .228	0.6 ± .204
Red June No. 499*						
Thinned portion	2.8 ± .028	10.3 ± .059	16.3 ± .104	7.5 ± .065	6.0 ± .119	13.5 ± .108
Unthinned portion	2.8 ± .023	9.0 ± .072	15.0 ± .099	6.2 ± .076	6.0 ± .122	12.2 ± .102
Difference	....	....	....	1.3 ± .100	0.0	1.3 ± .148
Red June No. 500*						
Unthinned	3.0 ± .030	9.5 ± .069	16.2 ± .105	6.5 ± .075	6.7 ± .125	13.2 ± .109
Wealthy No. 290*						
Thinned portion	2.4 ± .023	11.8 ± .058	20.9 ± .062	9.4 ± .062	9.1 ± .085	18.5 ± .066
Unthinned portion	2.3 ± .030	10.5 ± .100	20.8 ± .179	8.2 ± .104	10.3 ± .209	18.5 ± .181
Difference	....	....	....	1.2 ± .121	1.2 ± .226	0.0

*Refers to tree number.

TABLE 14.—Relative Increase in Volume of Fruits Thinned Before and After the June Drop, 1931

Variety and treatment	Volume of fruit			Gain in volume		
	May 26	June 24	Sept. 3	May 26 to June 24	June 24 to Sept. 3	May 26 to harvest
	cc.	*cc.*	*cc.*	*cc.*	*cc.*	*cc.*
Oldenburg No. 133*						
Thinned portion	0.4 ± 0.0031	48.4 ± 0.246	156.4 ± 1.028	48.0 ± 0.214	108.0 ± 1.057	156.0 ± 1.028
Unthinned portion	0.3 ± 0.0026	32.2 ± 0.216	154.0 ± 0.878	31.9 ± 0.246	121.8 ± 0.904	153.7 ± 0.878
Difference				16.1 ± 0.326	13.8 ± 1.391	2.3 ± 1.352
Oldenburg No. 132*						
Unthinned	0.4 ± 0.0024	27.7 ± 0.129	129.1 ± 1.749	27.3 ± 0.129	101.4 ± 1.754	128.7 ± 1.749
Oldenburg No. 400*						
Thinned portion	0.8 ± 0.0080	38.8 ± 0.217	135.1 ± 0.736	38.0 ± 0.217	96.3 ± 0.767	134.3 ± 0.736
Unthinned portion	0.6 ± 0.0098	27.7 ± 0.202	106.9 ± 0.872	27.1 ± 0.202	79.2 ± 0.895	106.3 ± 0.872
Difference				10.9 ± 0.296	17.1 ± 1.179	28.0 ± 1.141
Oldenburg No. 228*						
Thinned portion	0.2 ± 0.0022	45.3 ± 0.241	141.2 ± 0.918	45.1 ± 0.241	95.9 ± 0.949	141.0 ± 0.912
Unthinned portion	0.2 ± 0.0025	33.0 ± 0.214	129.1 ± 0.982	32.8 ± 0.214	96.1 ± 1.005	128.9 ± 0.982
Difference				12.3 ± 0.322	0.2 ± 1.382	12.1 ± 1.344
Red June No. 499*						
Thinned portion	0.4 ± 0.0040	18.4 ± 0.105	73.1 ± 0.466	18.0 ± 0.105	54.7 ± 0.478	72.7 ± 0.466
Unthinned portion	0.4 ± 0.0033	12.3 ± 0.098	57.0 ± 0.214	11.9 ± 0.098	44.7 ± 0.235	56.6 ± 0.214
Difference				6.1 ± 0.144	10.0 ± 0.533	16.1 ± 0.513
Red June No. 500*						
Unthinned	0.4 ± 0.0040	14.3 ± 0.105	71.8 ± 0.465	14.1 ± 0.105	57.3 ± 0.477	71.4 ± 0.465
Wealthy No. 290*						
Thinned portion	0.2 ± 0.0019	27.7 ± 0.136	154.0 ± 0.457	27.5 ± 0.136	126.3 ± 0.477	153.8 ± 0.457
Unthinned portion	0.2 ± 0.0026	19.5 ± 0.186	151.9 ± 1.307	19.3 ± 0.186	132.4 ± 1.320	151.7 ± 1.307
Difference				8.2 ± 0.230	6.1 ± 1.404	2.1 ± 1.384

*Refers to tree number.

TABLE 15.—Relation Between Size and Date of Harvest of Fruit from Trees Thinned Before and After the June Drop, 1931

Picking date	Percentage of fruit graded to size						Total crop (pounds)		Per cent of crop picked	
	Above 2¾ in.		Between 2¼—2¾ in.		Below 2¼ in.					
	Thinned before	Thinned after	Thinned before	Thinned after	Thinned before	Thinned after	Thinned before	Thinned after	Thinned before	Thinned after
Red June Tree 499 (thinned before) and 500 (thinned after)										
August 6	17.2	0.2	59.5	46.6	23.3	53.1	163	168	14.8	21.0
August 10	11.7	0.6	59.6	47.0	28.7	52.4	384	336	34.9	42.0
August 13	11.4	0.5	59.7	45.8	28.9	53.7	370	192	33.6	24.0
August 18	6.0	....	52.6	34.7	41.4	65.3	133	75	12.1	9.4
August 22	7.8	....	51.0	35.1	41.2	64.9	51	28	4.6	3.6
Total	11.5	0.4	58.4	45.1	30.1	54.5	1101	799	100	100
Oldenburg Tree 133 (thinned before) and 132 (thinned after)										
August 7	70.1	36.5	28.7	61.4	1.2	2.1	164	96	15.3	11.1
August 14	86.7	59.3	12.9	39.3	0.4	1.4	272	354	25.3	41.0
August 18	80.8	54.8	18.2	40.7	1.0	4.5	198	155	18.4	18.0
August 22	70.2	81.7	28.2	16.2	1.6	2.1	188	142	17.5	16.5
August 27	78.8	58.3	19.8	39.3	1.4	2.4	212	84	19.7	9.7
September 3	29.3	12.5	46.3	43.8	24.4	43.7	41	32	3.8	3.7
Total	76.5	57.8	21.6	38.4	1.9	3.8	1075	863	100	100

It is also to be noted that the trees thinned early had a much greater total number of pounds of fruit than the tree thinned later. This was undoubtedly due to the more even distribution of fruits on the early thinned tree. It was observed that it was much easier to space the fruits at the early thinning than at the thinning made after the June drop. Although it was not possible to eliminate the June drop entirely, the number abscising in this drop from the thinned branches was negligible and would likely be compensated for by the greater number of fruits left because of this more even spacing of the fruit-bearing clusters.

GENERAL CONSIDERATIONS

RELATION OF THE FRUIT-SETTING HABIT OF A VARIETY TO THINNING

The fruit-setting habit of a variety is an important factor in determining the desirability and the amount of thinning. Varieties which have retained several fruits per cluster until thinning time are more likely to require thinning than those varieties which normally average only one or two fruits per cluster. In this connection, it has already been pointed out (16) that apple varieties may be roughly placed in two groups on the basis of differences in their fruit-setting habit. In the first group are those which have a very heavy abscission shortly after blossoming and have, on the average, only one fruit per flowering point at thinning time. These are Delicious, Richared, Starking, Stayman, Winesap, Arkansas, Stamared, Blaxtayman, Tompkins King, Ohio Nonpareil, and Rhode Island Greening. In the second group, the first drop is usually light but the second or June drop may be fairly heavy. There are usually several fruits per cluster at thinning time on a larger number of the flowering points. Varieties in this group are Wagener, Wealthy, Grimes, York, Oldenburg, Winter Banana, Yellow Transparent, Rome, and Baldwin.

Investigators have been aware for some time that varieties showed differences in the amount of thinning required. Beach (4) indicated a difference between varieties in his conclusion that more of the fruit of Baldwin and Hubbardston required thinning than of Rhode Island Greening. Chandler (6) added McIntosh to Rhode Island Greening as a variety which, because of heavy fruit dropping, "will require little or no thinning". On the other hand, he stated that, with Wagener and Wealthy, thinning was nearly always necessary. Cummings, Jenkins, and Dunning (8) pointed out also that Rhode Island Greening was the extreme of a variety which required little or no thinning while Yellow Transparent was at the other extreme and required a great deal. They reported that Wealthy, Baldwin, Oldenburg, and Jonathan also required heavy fruit removal.

On the experiment reported herein with Grimes Golden, a very large proportion of the fruiting points at thinning time had several fruits each (Fig. 2). On the other hand, in Jonathan a much greater proportion of the fruiting points had one fruit (Fig. 3), while only a small percentage had two or more fruits. This was the result of a normally heavier June drop in the latter variety. This difference in the fruit-setting habit was responsible in large part for the difference in the results obtained from the thinning of these varieties. Without reducing the number of fruits on the fruiting points in Grimes, too great a proportion of the fruit would have been in the smallest size.

RELATION OF LEAF AREA TO THINNING

In the experiments reported in this bulletin the leaf area per fruit was considerably greater on the thinned trees than on the unthinned. Coincident with this increase in leaf area, there occurred an increase in the size of fruit. On the Grimes trees thinned to 8 inches, the volume of the fruit practically doubled with the doubling of the leaf area. As a matter of coincidence, Haller and Magness (14) also showed doubling of the volume of Grimes fruit when the leaf area per fruit was increased from 20 to 40 square inches. He obtained the largest fruit at 81 square inches of leaf area, but the branches were ringed. In Jonathan, the gain in volume on the thinned trees was, in general, somewhat less than in Grimes. Magness, Overley, and Luce (21) also failed to obtain as great an increase in size of Jonathan fruits from doubling the leaf area as in Grimes. Furthermore, in both varieties the gain in volume of fruit per increment increase in leaf area fell off rapidly above the 8-inch thinning. The fruits did tend, however, to increase in absolute weight at the greater thinning distances. Grimes in the dry year, 1930, proved an exception.

The color of the fruit of Jonathan was only slightly increased by thinning (Table 16). The color on the unthinned but pruned tree was also only slightly less than that of the thinned pruned trees. In fact, these experiments show a disappointing effect of thinning upon color development in this variety.

Fig. 2.—Grimes branch before and after 8-inch thinning.
Each square 12 inches

Fig. 3.—Jonathan branch before and after 8-inch thinning.
Each square 12 inches

The efficacy of all thinning rests upon its effectiveness in proportioning the fruits to the leaf area in order to give satisfactory size and color. Although the size and color of fruit will usually increase with the greater thinning distances, the reduction of total marketable fruit resulting is undesirable. This was evidenced in the wider Jonathan and Grimes spacing (Tables 20 and 22). Furthermore, the very largest fruits of Jonathan are scarcely desirable. Hunter (18) and Magness (20) have pointed out that Jonathan breakdown occurs more often with the largest Jonathan fruits and that the large-sized fruits of this variety are not desirable. The problem then centers around the attempt to regulate the leaf area so that the fruits at harvest will come within the desirable size range.

What leaf area produced the most marketable fruit? In Grimes, it ranged rather consistently from 48 to 56 square inches of leaf surface or about 50 leaves per fruit; with Jonathan, the area was about 40 to 50 square inches, or 25 to 30 leaves per fruit. Attempts have been made to recommend the amount of thinning desirable in terms of the number of leaves which should be left per apple. Thus, it can be seen that a rather general expression of the number of leaves desirable per fruit can be given, but the ability of the fruit grower to use this in a practical way is open to considerable question.

There are a number of advantages in recommending the amount of thinning on the basis of number of leaves per fruit, if such were practicable. In the first place, the recommendation would be made on the basis of an essential factor—namely, leaf area. Secondly, it makes possible the taking into consideration of differences in density of foliage. Thirdly, it would permit the consideration of differences in the flowering habit of the various varieties.

Recommendations on the basis of number of leaves per fruit have certain objections due to the mechanics of thinning. Since Haller (13) showed that leaf surface several feet from fruits will contribute to their size, all leaves on a large limb must be considered as functioning to produce size increases of the fruits on that limb, even though the fruiting points may be located toward the outer part of the branch and the leaves toward the inner part. The fruit grower in attempting to use "leaves per fruit" as the index of amount of thinning would be forced to count all leaves on a branch in order to calculate the number of fruits which should remain. Furthermore, by expressing thinning in terms of number of leaves, no account is taken of differences in size of leaves. Finally, this method does not take into account possible differences in photosynthetic activity of a given unit of leaf surface.

Although recommendations of the amount of thinning expressed on the basis of a minimum distance between adjacent fruiting points are also open to a number of the same objections as recommendations based on number of leaves, the writers feel that, at present, the former is the most usable index for the average fruit grower.

On thinning, the fruit-bearing points are usually reduced to one fruit and no fruiting points permitted within a given minimum distance from each other along an axis (Figs. 2, 3). If leaf area were the only factor affecting size and color increase, it might be considered from a theoretical viewpoint that several fruits per cluster would be as satisfactory as the same number of fruits left singly, provided the leaf area per fruit was the same in both cases. Would it then be advisable to leave two fruits per cluster and only half as many fruiting points? The writers suggest that some other factor may reduce the total weight of fruits if two are left to a cluster; namely, the conduction capacity of the vascular system of the spur, shoot, or cluster base. Experimental evidence along this line is desirable.

On the basis of present evidence, it seems more desirable to thin the clusters to one fruit each and then separate the fruiting points a minimum distance from each other. This minimum distance will vary with the flowering habit of the variety. In Grimes (Fig. 2), the fruiting points were spaced to a minimum distance of 10 inches with best results. Where thinning is done in Jonathan (Fig. 3), these experiments indicate that a minimum distance of 6 to 8 inches would be more desirable than a wider one.

RELATION OF THE FLOWERING HABIT OF A VARIETY TO THINNING

Apple varieties differ in the distance between adjacent flowering points along the branch axis. On Wealthy, for example, a large proportion of its fruit buds may be borne on short spurs; whereas, on Rome, they will be formed terminally on rather long shoots. On Grimes, the fruit buds, as indicated in Figure 2, are largely borne terminally on rather short shoots. In Jonathan, as indicated in Figure 3, the fruit buds were borne on spurs and shorter shoots than in Grimes. It is thus apparent that in these varieties a given minimum thinning distance would not remove equal numbers of fruiting points.

Approximately 100 per cent of the flowering points of Jonathan and Grimes in these experiments had set fruit. Therefore, it is possible to arrive at the approximate mean distance between adjacent flowering points in these varieties by taking the mean distance between adjacent fruiting points from Table 2. In Grimes, in 1928, it was 10 inches and in 1930, 8 inches. In Jonathan, it was 7.4 inches. This substantiates the observation previously made that there was a shorter mean distance, in general, between adjacent flowering points in Jonathan than in Grimes.

This shorter mean distance between adjacent fruiting points in Jonathan thus indicates that the 8-inch thinning distance would remove a greater proportion of the fruiting points in Jonathan than in Grimes. Proof of this is presented when comparison is made of the percentage of fruits removed at the 8-inch distance in the two varieties (Tables 20 and 22). The data show that the percentage of fruits removed by the 8-inch thinning was only slightly less in Jonathan than in Grimes. When it is considered that the Jonathan fruiting points had fewer fruits than Grimes (Compare Fig. 2 with 3), the greater removal of fruiting points in Jonathan is obvious. The 8-inch thinning distance then represented a more severe thinning in Jonathan than in Grimes. In fact, in Grimes the 8-inch thinning consisted rather largely of reducing the number of fruits in the fruiting clusters to one fruit. After such reduction, only a relatively few fruiting points required removal. Substantiation of this is found in the data for 1930. One tree had the fruits thinned to one fruit per cluster, but no fruiting points were removed. This thinning removed 41 per cent of all fruits on the tree; this value, as indicated in Table 20, was approximately equal to the per cent of the fruits removed at the 8-inch thinning distances.

To express thinning in terms of a minimum thinning distance has value only when it takes into account the flowering habit of a variety. To attempt to apply an 8-inch thinning, for example, to all varieties is unjustifiable. In Delicious and Rome the spacing distance must be greater than 8 inches to remove the same proportion of fruiting points as would be removed with either Jonathan or Grimes.

RELATION OF PRUNING TO THINNING

A number of investigators, Whipple (25) and Chandler (7) for example, have pointed out that pruning and thinning are related. Chandler (7) stated that the amount of thinning depended upon the amount of pruning. In the thinning experiments reported herein, the favorable effects of pruning Jonathan masked the response obtained by thinning. Data in support of this point are given in Table 16. It is to be noted that, on the unpruned tree which was thinned to 8 inches, more fruit was of the smaller size grades than on the pruned tree thinned to 8 inches. Furthermore, the unpruned thinned tree had no better color than the pruned, but unthinned, tree. Pruning thus maintained the color in Jonathan to the point where thinning was unable to give an appreciably greater response.

TABLE 16.—Inter-relationship of Pruning and Thinning Upon the Size and Color of Fruit, Jonathan
Average for 2 years, 1929 and 1931

Pruning Treatment	Thinning distance	Size grades			Color grades		
		Above 2¾ in.	2¼ to 2¾ in.	Under 2¼ in.	U. S. Fancy	U. S. No. 1	Under U. S. No. 1
		Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Moderate	Not thinned	6.5	75.5	18.0	78.4	15.6	6.0
Moderate	8-inch	20.9	73.5	5.6	81.7	15.3	3.0
Moderate	10-inch	26.9	69.7	3.4	83.3	14.5	2.2
Moderate	12-inch	39.4	57.7	2.9	83.9	13.6	2.5
Moderate	14-inch	34.5	62.6	2.9	84.0	13.3	2.7
Unpruned	8-inch	0.7	71.7	27.6	79.3	15.9	4.8
Unpruned	10-inch	15.7	82.3	2.0	72.3	24.7	3.0

Pruning has well known effects upon fruit bud formation, upon the maintenance of tree growth and vigor, and upon efficient control of insect pests and diseases. These advantages are also attributed to thinning. Magness, Overley, and Luce (21) obtained data showing the production of fruit buds 2 years in succession on thinned branches.

The question arises as to whether proper pruning should not make the practice of thinning unnecessary.

The answer depends upon several factors, the most important of which may possibly be the varietal one. With some varieties more than with others, intelligent pruning would tend to bring about the production of fruit of satisfactory size, color, and quality without the further necessity of thinning. With those varieties such as Grimes and Yellow Transparent which usually have several fruits per cluster at thinning time, pruning will not be nearly so efficacious in supplanting thinning as in those varieties which have an average of only one fruit per cluster. To be sure, pruning would tend to increase the size and color of varieties which hold several fruits per cluster through the June drop, but it obviously cannot reduce the number of fruits on a fruiting point. The pruning would be too severe if it made thinning of these varieties unnecessary, and it is to be recalled that pruning, like thinning, when overdone also reduces the total yield of marketable fruit.

TABLE 17.—Time Required to Prune and Remove Brush from Grimes and Jonathan (Spring of 1932)
Trees planted 1900

Plot	Time required per tree for pruning Minutes	Time required per tree to pick brush Minutes
	Grimes	
Not thinned	24.0	2.5
8-inch	42.0	3.0
10-inch	36.0	4.0
12-inch	54.3	5.0
14-inch	36.0	3.0
	Jonathan	
Not thinned	30.0	5.0
8-inch	25.5	3.5
10-inch	31.5	3.0
12-inch	34.0	3.7
14-inch	40.5	3.8

On those varieties which experience a normally heavy June drop, such as Jonathan, intelligent pruning may maintain such favorable size and color that thinning will be unnecessary, especially where immediate expense must be curtailed. Pruning requires less time than thinning, as can be observed by a comparison of Tables 17 and 19.

The experiments in this bulletin suggest that the advisability of thinning trees following an intelligent pruning depends upon the varietal factor. The writers believe that pruning should be the regular, annual practice with bearing trees of all varieties and that the necessity of thinning the fruit of a particular variety will depend largely upon its fruit-setting habit.

RELATION OF NITROGEN-CARRYING FERTILIZERS TO THINNING

There seems to be little question that the number of fruits on a tree is the most important factor affecting the size of fruit and the development of satisfactory color. Nitrogen-carrying fertilizers, in so far as they increase the set of fruit over that required for a full crop, will likely have an unfavorable effect upon size. In this connection, Gaston (10), in discussing the indirect causes of culls in Michigan, stated that nitrogen-carrying fertilizers often have a tendency to result in the production of fruit lacking in size (the chief characteristic of culls in that State). The suggestion was made that judicious thinning would increase the net income by maintaining satisfactory size.

It has been suggested that the application of nitrogen-carrying fertilizers after bloom rather than before might be a means of preventing excessive fruit setting. With those varieties requiring heavy thinning (these have proved to be our most dependable varieties), the application of the fertilizer after bloom may be a step in the right direction. It is, however, entirely possible that the nitrogen reserve carried over by the trees from a previous after-bloom application might maintain the set at a point where heavy thinning would still be required. In the case of the varieties having only one or two fruits per cluster and requiring only light thinning, an after-bloom application hardly seems wise.

Although the nitrogen-carrying fertilizers are necessary in many commercial orchards, their use must be correlated with other practices affecting size and color of fruit. Fertilization with nitrogen without pruning is hardly a wise practice unless the fruit is properly thinned out. Fertilization with nitrogen and intelligent pruning appear to be essential to the production of high yields of good quality fruit. In addition, the practice of thinning the fruit may still be necessary to insure that these benefits are not jeopardized by excessive fruit setting.

RELATION OF THINNING TO MOISTURE SUPPLY

Grimes Golden gave a very favorable response to thinning during the year 1930, which was very deficient in rainfall, Table 3. Since moisture supply is an important factor in the development of the proper size and color of fruit,thinning will consequently produce more favorable results during seasons when the rainfall is deficient. As far as possible, all the factors affecting moisture supply should be given proper consideration in the program of the commercial orchard; this involves proper planting distance between trees, incorporation of organic matter into the soil, and a satisfactory growth of cover crops. In the Pennsylvania experiments with York and Baldwin as reported by Anthony (2), the satisfactory size of fruit attained without thinning during the dry years has been attributed to the large amount of organic matter incorporated in the soil. There is no doubt that the importance of this factor in maintaining size and color of fruit in our Ohio orchards has not been emphasized as much as experimental evidence now available would justify.

INFLUENCE OF THINNING UPON REGULARITY OF BEARING

Comparing the crop of Grimes in the two light-crop years 1929 and 1931 (Table 20), we find the number of apples present on each thinned plot was appreciably greater in 1931, the third year of the experiment, than in 1929. Making the same comparison of Jonathan for the heavy-crop years 1929 and 1931 (Table 22), we again find a greater percentage gain of apples present on the thinned than on the unthinned trees. While this may indicate that regular annual thinning tends to increase flower formation on these varieties, more data are needed before definite conclusions can be made. There seemed to be no consistent difference between the several thinned plots so far as the set of fruit was concerned.

Practically all of the thinning experiments reported have been based on data from trees which had reached full bearing age when the work was started. In most instances, too, these experiments have not continued on the same set of trees over a sufficient length of time to expect any change in the "off year" crop. Commercial thinning is not usually started until the formation of fruit buds for the succeeding year has already begun, and no appreciable results could be expected in increased yields from a single year's thinning.

It is likely that regular annual thinning helps to maintain the trees in uniform vigor from year to year. This is very apparent in periods of drouth. During the exceptionally dry summer of 1930, unthinned trees in the Station orchard were noticeably more wilted than thinned trees of the same variety. This was especially true of Grimes. The practice of thorough thinning followed annually in the northwest apple-growing sections has frequently been credited as an important factor in inducing the heavy yields common in that section.

Whatever influence thinning may have on regularity of bearing, there is no evidence to suggest that it can correct habitual alternate bearing, inherent in certain varieties, once that habit is well established. Beach (4) found from experiments, extending over 4 years, with mature Baldwin trees that thinning exerted no influence on the regularity of fruit production in the off year.

The removal of a portion of the fruit from heavily loaded trees early in the year will decrease the drain on the food and moisture available. Thinning, therefore, may be grouped with pruning and fertilization as one of the cultural practices which tends to induce and maintain vigor.

MINOR EFFECTS OF THINNING

RELATION TO GRADING

As stated elsewhere, the principal influence of thinning on quality of harvested apples is reflected in the grades of larger size. It has also been pointed out that thinning may improve color. In practice, thinning provides an opportunity for improving the general quality of the fruit by eliminating disease- and insect-blemished specimens, as well as those that are lop-sided or mechanically injured. In commercial thinning, preference is always given to the larger apples, and this is a factor in increasing the average size of the fruit. Cummings, Jenkins, and Dunning (8) have shown that the smaller apples of most varieties gained relatively more in size during the growing season than larger specimens. However, apples which were undersized at the time thinning was done were still small at harvest time.

The removal of irregularly shaped or disease- and insect-marked specimens by thinning does not entirely eliminate defective apples at harvest time, but grading costs may thereby be reduced. Late-season injuries from disease and insect pests and such mechanical injury as limb rub may develop after the thinning is done. The second-brood codling moth usually appears after thinning is completed. Where this pest is serious the percentage of sideworms and stings resulting may be as numerous on thinned as on unthinned trees. However, early-season elimination of cull apples is one of the somewhat intangible but actual benefits often derived from thinning. When apple scab is serious early in the year, thinning provides an opportunity for eliminating many of the scab-deformed apples. Thorough spraying early in the year, as well as good pruning, reduces the amount of defective fruit on the trees at thinning time.

TABLE 18.—Influence of Thinning on Removal of Defects
Percentage of fruit showing defects at harvest time
[After—Cummings, Jenkins, and Dunning (8)]

	Fameuse	Wealthy	Tolman	McIntosh	Arctic	Average
Thinned	8.1	11.0	6.3	9.1	14.4	9.8
Unthinned	13.0	12.8	11.7	5.2	11.0	10.7

Several years ago observations (not published) were made in the Station orchards on the quantity of blemished fruit on a number of trees at thinning time and again at harvest time. It was revealed from a number of observations that only a few of the thinned trees had a lower percentage of defective apples at harvest time than they did when thinned. Cummings, Jenkins, and Dunning (8), in Vermont, found that thinned trees usually had only slightly fewer defective apples at harvest time than unthinned trees in the same orchard, Table 18.

THINNING VERSUS PROPPING

Many varieties of apples frequently set so heavily that they must either be thinned or propped to prevent breakage. Propping does not always prevent limb breakage as may be noted in the illustration (Fig. 4). Propping is more quickly accomplished than thinning if props are readily available. However, the preparation of props from saplings or branches of large trees entails considerable labor and consumes more time than might be expected. Props of the kind shown in Figure 4 are made from boards 1 inch or more in thickness and 4 to 6 inches wide. The props illustrated had a semi-circular notch sawed in one end of the board to permit rapid placement under the limb. Delivered in the orchard in 1931, these props cost: (1) 6-foot length, 8½¢; (2) 8-foot, 12¢; (3) 10-foot, 16¢. The number of props required per tree for mature trees ranges from 6 to 10, depending upon size of tree and prop. Six-foot props can be used for trees 10 years old or less. For mature trees, props at least 10 feet long or longer are nearly always required.

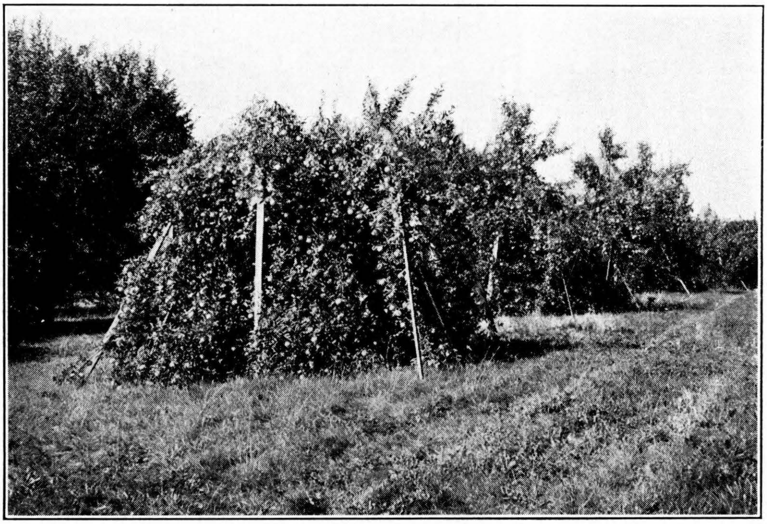

Fig. 4.—Unthinned trees often require propping

PREVENTION OF LIMB BREAKAGE

There are no data available as to the influence of thinning on the prevention of limb breakage. This is another of the benefits from thinning which it is difficult to express in monetary value. It is well understood, however, that unthinned and unpropped trees are often permanently damaged when overloaded. Of course, a certain amount of bending and opening up of young trees is desirable, especially with varieties which tend towards an upright growth when young. By thorough and uniform thinning throughout a tree, limb breakage can be reduced to a minimum. Thinning is closely related to pruning as a means of preventing limb breakage.

COST OF THINNING

The cost of thinning depends upon the speed with which the work is accomplished and the hourly wage. The speed with which thinning may be done depends upon the form of the tree, the pruning practiced, general variety characteristics, and the agility of the workman. The use of shears as pointed out elsewhere slows up the operation. The number of apples an average workman will remove in an hour ranges from 400 to 1500, depending upon the conditions cited above. In Table 19 are presented some records taken in the Station orchards showing the number of apples removed per hour. In most cases these figures represent the average of several workmen. The records on Grimes, Jonathan, and McIntosh shown in

TABLE 19.—Time Consumed in Thinning

Variety	Age of trees	Distance of thinning	Method of thinning	Apples removed hourly per man
	Years	*Inches*		*Number*
Baldwin	19	8	Shear	758
Golden Delicious	8	8–10	Shear	924
Grimes	Mature	8–10	Shear	661
Grimes	Mature	12–14	Shear	741
Jonathan	Mature	8–10	Shear	395
Jonathan	Mature	8–10	Hand	819
Jonathan	Mature	12–14	Shear	384
Jonathan	Mature	12–14	Hand	785
McIntosh	Mature	6– 8	Shear	471
Mother	Mature	8–10	Shear	1104
Mother	Mature	8–10	Hand	1539
Oldenburg	19	6– 8	Shear	590
Stayman Winesap	15	8–10	Shear	1002
Stayman Winesap	15	8–10	Hand	1131
Wilson Red June	Mature	8–10	Shear	912
Wilson Red June	Mature	8–10	Hand	1068
Yellow Transparent	Mature	8–10	Hand	1028
Average number of apples removed hourly per man				Shear 722, Hand 1062

this table were taken from the experimental thinning plots and were influenced by the greater care required in this type of work. The other data in Table 19 were taken from commercial thinning experience.

The use of shears decreased the speed of thinning 10 to 50 per cent. It usually took one man from 2 to 3 hours to thin an average mature tree bearing a full crop of fruit. The time required per tree for thinning varieties which tend to set heavy crops, like Grimes, Jonathan, and Yellow Transparent, is considerably greater than for such varieties as Delicious and Stayman. Thinning is also relatively much faster on smaller trees where most of the apples may be removed without the use of a ladder.

Murneek (22), in Missouri, reported that thinning trees yielding 10 to 15 bushels cost approximately 3 cents per harvested bushel and that, with the scale of wages around 25 cents per hour, low headed trees could be thinned for 2 cents per bushel. On higher trees the cost increased to 4 cents per bushel.

TABLE 20.—Effect of Thinning Grimes Upon Yield and Size
1929-1930-1931
(In connection with Table 21)

Thinning distance	No. of trees	Apples per tree before thinning	Apples removed by thinning	Actual weight of harvested apples	Corrected weight of harvested apples	Size grades		
		Number	Per cent	Pounds	Pounds	Above 2¾ in.	2¼ to 2¾ in.	Under 2¼ in.
1929 (Light crop)								
Not thinned	2	1678	....	286	449	11.4	54.8	33.8
8-inch	2	3793	47.2	525	365	48.0	50.2	1.8
10-inch	3	487	56.9	80	433	76.6	21.7	1.7
12-inch	3	2753	57.9	353	339	73.7	25.7	0.6
14-inch	2	5508	61.7	555	266	43.0	54.9	2.1
1930 (Heavy crop)								
Not thinned	2	6097	....	711	921	0.0	20.2	79.8
8-inch	2	8733	41.0	1020	909	10.2	78.8	11.0
10-inch	3	9970	45.0	1173	930	9.9	82.7	7.4
12-inch	3	8348	42.0	1022	968	2.0	88.0	10.0
14-inch	2	4476	50.0	502	885	26.2	65.6	8.2
1931 (Light crop)								
Not thinned	2	1054	....	226	780	24.8	61.4	13.8
8-inch	2	4589	45.5	701	556	55.2	44.0	0.8
10-inch	3	3060	44.0	569	677	74.6	24.6	0.8
12-inch	3	2973	50.2	400	490	54.2	44.5	1.3
14-inch	2	7168	53.2	944	481	53.1	45.4	1.5
3-year average								
Not thinned	2	2493	....	406	717	12.1	42.1	45.8
8-inch	2	5706	44.6	749	610	37.8	57.7	4.5
10-inch	3	4506	48.6	607	680	53.7	43.0	3.3
12-inch	3	4691	50.0	592	599	43.3	52.7	4.0
14-inch	2	5717	55.0	667	544	40.8	55.3	3.9

Johnson (19), in Washington, showed that, during a 3-year period, it cost from $15.56 to $40.18 per acre for thinning and that from 63.6 to 74.9 man hours were consumed per acre in this work in orchards bearing heavy crops.

Auchter (3), in West Virginia, found that 1140 apples per hour were the average removed per man.

In the experiments reported upon herein it has not been possible to distribute the cost of labor properly between thinning and harvesting. At least part of the cost of thinning should properly be charged as a harvesting cost. It is difficult to determine just how much thinning reduces the cost of picking. However, the cost per bushel for picking the unthinned Grimes and Jonathan was appreciably more than for the thinned trees. Grading charges are also often higher on unthinned trees. In such instances as the Grimes, Table 20, where the percentage of small apples on unthinned trees is relatively high, this difference in grading charges

TABLE 21.—Effect of Thinning Grimes Upon Value of Fruit
Yield and size considered, 1929-1930-1931
(In connection with Table 20)

Thinning distance	No. of trees	Gross value per pound Dollars	Gross value of fruit per tree		Gain per tree, yield and size considered (Corrected weight) Dollars
			Actual weight	Corrected weight	
1929 (Light crop)					
Not thinned	2	0.0244	6.96	10.95	....
8-inch	2	0.0344	18.06	12.58	1.63
10-inch	3	0.0373	2.97	16.16	5.21
12-inch	3	0.0372	13.16	12.63	1.68
14-inch	2	0.0339	12.54	9.02	— 1.93
1930 (Heavy crop)					
Not thinned	2	0.0140	9.98	12.93	....
8-inch	2	0.0288	29.37	26.20	13.27
10-inch	3	0.0295	34.61	27.44	14.51
12-inch	3	0.0282	28.80	27.30	14.37
14-inch	2	0.0301	15.54	27.42	14.49
1931 (Light crop)					
Not thinned	2	0.0083	1.88	6.47	....
8-inch	2	0.0102	7.12	5.67	— 0.82
10-inch	3	0.0109	6.23	7.38	0.94
12-inch	3	0.0101	4.04	4.95	— 1.52
14-inch	2	0.0100	9.49	4.81	— 1.64
3-year average					
Not thinned	2	0.0156	6.27	10.12	....
8-inch	2	0.0245	18.18	14.81	4.69
10-inch	3	0.0259	14.60	16.99	6.87
12-inch	3	0.0252	15.33	14.96	4.84
14-inch	2	0.0247	12.52	13.75	3.63

TABLE 22.—Effect of Thinning Jonathan Upon Yield, Size, and Color
1929-1930-1931
(In connection with Table 23)

Thinning distance	No. of trees	Apples per tree before thinning	Apples removed by thinning	Actual weight of harvested apples	Corrected weight of harvested apples	Size grade			Color grade		
						Above 2¾ in.	2¼ to 2¾ in.	Under 2¼ in.	U. S. Fancy	U. S. No. 1	Under U. S. No. 1
		Number	Per cent	Pounds	Pounds	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
1929 (Heavy Crop)											
Not thinned	2	4614	....	854	833	11.1	77.5	11.4	72.3	20.8	6.9
8-inch	2	4305	35.0	692	726	40.2	58.4	1.4	78.1	20.8	1.1
10-inch	4	4695	42.0	659	632	41.4	57.1	1.5	78.6	19.9	1.5
12-inch	3	3932	39.0	636	731	58.4	40.2	1.4	83.1	15.6	1.3
14-inch	4	4790	49.0	625	590	47.9	50.6	1.5	85.4	13.3	1.3
1930 (Light Crop)											
Not thinned	2	1225	....	237	492	14.2	79.5	6.3	96.2	3.8	0.0
8-inch	2	2168	42.4	326	387	59.0	40.2	0.8	92.2	7.8	0.0
10-inch	4	2913	41.9	388	338	31.0	66.9	2.1	95.2	4.7	0.1
12-inch	3	2453	31.7	423	437	40.0	58.9	1.1	96.4	3.5	0.1
14-inch	4	3065	44.3	408	338	45.7	53.5	0.8	94.3	5.4	0.3
1931 (Heavy Crop)											
Not thinned	2	6865	....	1166	1394	1.8	73.6	24.6	84.5	10.3	5.2
8-inch	2	8526	34.2	1207	1161	1.5	88.7	9.8	85.2	9.8	5.0
10-inch	4	8143	41.2	1016	1022	12.4	82.4	5.2	87.9	9.1	3.0
12-inch	3	7452	38.4	997	1097	20.4	75.2	4.4	84.6	11.5	3.9
14-inch	4	9338	43.4	1171	1031	21.1	74.6	4.3	82.5	13.3	4.2
3-year average											
Not thinned	2	4235	....	752	906	9.0	76.9	14.1	84.3	11.6	4.1
8-inch	2	4999	37.2	742	758	33.6	62.4	4.0	85.2	12.8	2.0
10-inch	4	5250	41.7	688	664	28.3	68.8	2.9	87.2	11.2	1.6
12-inch	3	4612	39.7	685	755	39.6	58.1	2.3	88.0	10.2	1.8
14-inch	4	5731	45.6	735	653	38.2	59.6	2.2	87.4	10.7	1.9

may be a significant factor in determining the net thinning cost. In commercial thinning it is the universal practice to remove defective specimens. This practice also tends to decrease grading charges per bushel.

TABLE 23.—Effect of Thinning Jonathan Upon Value of Fruit
Yield, size, and color considered, 1929-1930-1931
(In connection with Table 22)

Thinning distance	No. of trees	Gross value per pound Dollars	Gross value of fruit per tree		Gain or loss per tree, yield and size of fruit considered (Corrected weight) Dollars	Gain per tree, due to color Dollars	Gain or loss per tree, size and color considered Dollars
			Actual weight	Corrected weight			
1929 (Heavy crop)							
Not thinned...	2	0.0288	24.62	23.99	....	....	....
8-inch	2	0.0337	23.34	24.47	0.48	1.26	1.74
10-inch	4	0.0338	22.27	21.36	−2.63	1.08	−1.55
12-inch	3	0.0356	22.64	26.02	2.03	1.61	3.64
14-inch	4	0.0345	21.56	20.36	−3.63	1.43	−2.20
1930 (Light crop)							
Not thinned...	2	0.0303	7.18	14.91	....	....	....
8-inch	2	0.0358	11.67	13.85	−1.06	−0.19	−1.25
10-inch	4	0.0327	12.69	11.05	−3.86	−0.04	−3.90
12-inch	3	0.0338	14.30	14.77	−0.14	0.00	−0.14
14-inch	4	0.0344	14.04	11.63	−3.28	−0.08	−3.36
1931 (Heavy crop)							
Not thinned...	2	0.0068	7.93	9.48	....	....	....
8-inch	2	0.0076	9.17	8.82	−0.66	0.04	−0.62
10-inch	4	0.0082	8.33	8.38	−1.10	0.25	−0.85
12-inch	3	0.0086	8.57	9.43	−0.05	0.07	0.02
14-inch	4	0.0086	10.07	8.87	−0.61	−0.03	−0.64
3-year average							
Not thinned...	2	0.0220	13.24	16.13	....	....	....
8-inch	2	0.0257	11.43	15.71	−0.41	0.37	−0.04
10-inch	4	0.0249	14.43	13.60	−2.53	0.43	−2.10
12-inch	3	0.0260	15.17	16.74	0.61	0.56	1.17
14-inch	4	0.0258	15.22	13.62	−2.51	0.44	−2.07

SUMMARY

The results from thinning Grimes and Jonathan for a 3-year period and from early thinning of early varieties are presented.

Thinning Jonathan at any distance reduced the total weight of harvested fruit per tree. With few exceptions, this reduction was in proportion to the degree of thinning.

Thinning also reduced the weight of the harvested crop of Grimes but not so greatly as was true with Jonathan.

Thinning Jonathan, regardless of distance, materially increased the size of the fruit. Eight- and 10-inch thinning resulted in similar size grades; 12- and 14-inch thinning also resulted in similar size grades, slightly superior to those secured from the 8- and 10-inch thinning.

Thinning influenced the size of Grimes to a greater extent than was true with Jonathan.

The cull grade of Grimes in 1930 amounted to 80 per cent of the total harvested fruit on unthinned trees; on none of the thinned plots did the culls exceed 11 per cent.

Thinning slightly improved the color of Jonathan. Pruning was shown to have a much greater influence on color than thinning.

Pruning unthinned trees had a more favorable influence on size than was secured from thinning unpruned trees to 8 inches.

Results seem to indicate that annual thinning tends to increase size of off-year crops, but more data are required before definite conclusions are warranted.

Thinning reduces, but may not obviate, the necessity for propping and reduces or may entirely eliminate all limb breakage.

The response to thinning is particularly favorable in dry seasons.

The varietal difference in the response to thinning was emphasized in total yields of Grimes and Jonathan on thinned plots.

Average workmen removed 722 apples per hour with shears and 1062 by hand. Shears are almost a necessity with some varieties and are particularly useful after the stem becomes woody.

With Grimes, in 1930, the leaf area per fruit on the trees thinned to 8 inches was approximately double that on the unthinned trees. Coincident with this increase in leaf area, the gain in average weight per fruit was 86 per cent. With further increase in leaf area there was not a corresponding increase in weight of the fruit.

With Jonathan, in 1929, the leaf area per fruit on the trees thinned to 8 inches was 60 per cent greater than on the unthinned trees. The gain in circumference was equivalent to a gain in volume per fruit of 70 per cent. In 1931, the leaf area per fruit on the trees thinned to 8 inches was 86 per cent greater than on the unthinned trees. The gain in circumference was equivalent to a gain in volume of 30 per cent. In both years the fruits increased in size up to the 12-inch thinning.

In general, the increase in size of fruit per unit increase in leaf area was greater with Grimes than with Jonathan.

On the basis of leaf area and size increase per fruit, the thinning distances fell into two groups; namely, 8 and 10, and 12 and 14 inch.

In the experiments on the early thinning of Yellow Transparent, Oldenburg, Red June, and Wealthy, 87 to 99 per cent of the fruits not removed at thinning time remained on the trees through the June drop.

The Oldenburg and Red June trees thinned before the June drop produced considerably larger fruit than those thinned after.

Thinning before the June drop required a longer time than thinning after.

Thinning early ripening varieties as early as possible, even before the June drop, is suggested where satisfactory size and color are not being obtained with the thinning now practiced.

There seems little to justify the selection of fruits at thinning time other than on the basis of size and freedom from blemishes.

The expression of the amount of thinning in Grimes and Jonathan in terms of a minimum distance between adjacent fruiting points seems to the writers to be more practical than expression in terms of number of leaves per fruit.

Ten-inch thinning gave the most favorable response on Grimes of any distance used, size of fruit and total weight considered.

Eight-inch thinning was most satisfactory for Jonathan. The writers suggest that Jonathan be thinned to from 6 to 8 inches.

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